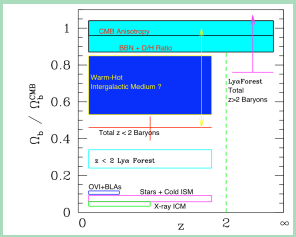
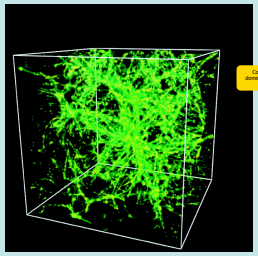
XMM-Newton Confirmation of the OVII WHIM detections along the Line of Sight to Mkn 421

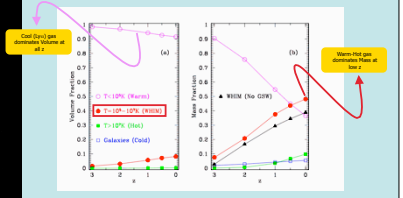
(Nicastro, F, Conciatore M.L., Mathur, S., Elvis, M, Williams, R.)

The *Missing Baryon* Problem



The *Warm-Hot Intergalactic Medium Solution*





(Cen & Ostriker, 2006)

2 WHIM systems detected with the Chandra-LETG along the line of sight to Mkn 421: Controversial Evidence?

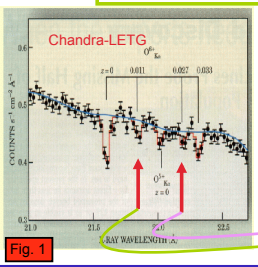


Fig. 1

Nicastro+05, Nature, ApJ

Transition	Redshift	Equivalent Width (mÅ)
OVII Kα	0.011 ± 0.001	3.0 (+0.9, -0.8)
OVII Kα	0.027 ± 0.001	2.2 ± 0.8

Table 1

Rasmussen+07, ApJ

Table 2

Transition	Redshift	Equivalent Width (mÅ)
OVII Kα	0.011 ± 0.001	< 2.3 (1.6σ)
OVII Kα	0.027 ± 0.001	< 2.3 (1.6σ)

Continuum is too low!
…Still EW upper limits are consistent with Chandra measurements

5-10 bins per resolution element

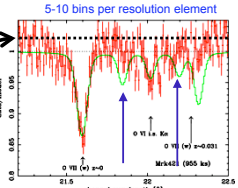


Fig. 2

XMM-RGS Spectrum of Mkn 421: **Standard** Reduction

2-4 bins per resolution element

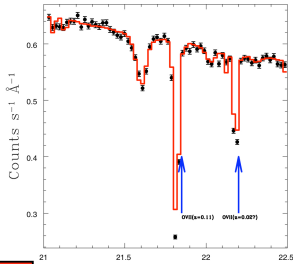


Fig. 3

21-22.5 Å portion of the XMM-RGS1 spectrum of Mkn 421. Two deep instrumental features due to bad-pixels are present in ~60% (21.75-21.85 Å) and ~30% (22.18-22.22 Å) of the 39 observations, at slight different wavelengths due to slight different 0th-order detector coordinates. The two instrumental features cover the positions of the two OVII WHIM absorbers, and so make the them undetectable in this version of the RGS spectrum. Note that the averaged response does not properly match the data at the positions of the instrumental features. This leads to net negative residuals, as shown in Fig. 4. Part of these residuals may be due to the actual presence of the two OVII intervening absorbers.

Standard (SAS) reduction

- We retrieved from the public XMM-Newton archive 39 observations of Mkn 421 (6 more than in Rasmussen+07)
- We reduced the data following the standard SAS (v. 7.1.2) threads for the extraction of RGS spectra, and switching off the "NEXT_TO_BADPIX" *rgsproc* "switch".
- After cleaning for periods of high background, the final RGS spectrum has a net exposure of 1061.8 ksec (106 ksec more than the spectrum published by Rasmussen+07)
- Here we concentrate on the 21-22.5 portion of the RGS1 (the only available in this spectral range) spectrum, where the two intervening OVII WHIM absorbers detected with the Chandra LETG lie.
- The 21-22.5 portion of the spectrum is shown in Fig. 3, while residuals to the best model are shown in Fig. 4.

Transition	Redshift	Equivalent Width (mÅ)
OVII Kα	0.011 (fixed)	3.8 ± 1.0
OVII Kα	0.027 (fixed)	3.5 ± 1.0

Table 3

Residuals (in σ) to the best best fitting model

2-4 bins per resolution element

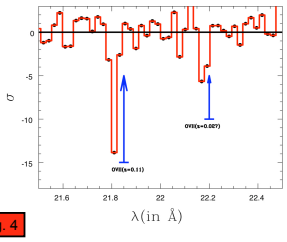


Fig. 4

Residuals, in σ, to the best fitting model (consisting of a powerlaw corrected by a multiplicative 'spline' model, and three negative gaussians at the positions of the z=0 OVII Kα and OVI Kα, and the $z=z_{sou}$ OVII Kα) of the 21-22.5 portion of the total RGS spectrum of Mkn 421 obtained by following the standard reduction SAS threads. The two deep features are at positions consistent with the two intervening OVII lines detected in the LETG spectrum of Mkn 421. Most, if not all, of these residuals are due to uncertainties in the averaged RGS effective area model, These two large positive deviations are also fully consistent with the presence of thw two intervening OVII Kα lines detected in the Chandra LETG spectrum of Mkn 421 (cf EWs in Table 3 with EWs in Table 1).

XMM-RGS Spectrum of Mkn 421: **Non-Standard** (R07) Reduction

2-4 bins per resolution element

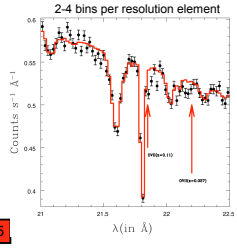


Fig. 5

21-22.5 Å portion of the XMM-RGS1 spectrum of Mkn 421 published by Rasmussen and collaboratators, together with its best fitting model continuum (plus three negative gaussians at the positions of the z=0 OVII Kα and OVI Kα, and the $z=z_{sou}$ OVII Kα) model. Only one of the two deep instrumental features that were present in the version of the spectrum obtained via standard reduction (Fig. 3), is present in the spectrum reduced by Rasmiussen and collaborators via a careful non-standard data reduction procedure elaborated by the authors. This feature appear less prominent, and narrower that in the spectrum of Fig. 3. This allows to clearly detect two moderate deficits of counts at the positions of the two OVII WHIM lines detected in the Chandra spectrum of Mkn 421 (red arrows), confirming the presence of these two absorbers.

Non-Standard (Rasmussen07+) reduction

- A. Rasmussen and collaborators kindly provided us with their version (see R07) of the RGS1 spectrum of Mkn 421 and responses.
- The spectrum has a net exposure of 955.9 ksec (106 ksec less than the spectrum reduced by us and shown in Fig. 4)
- The 21-22.5 portion of the spectrum is shown in Fig. 5, while residuals to the best model are shown in Fig. 6.

Transition	Redshift	Equivalent Width (mÅ)
OVII Kα	0.011 ± 0.001	3.2 ± 0.5
OVII Kα	0.027 ± 0.001	2.2 (+0.6, -1.0)

Table 4

Residuals (in σ) to the best best fitting model

2-4 bins per resolution element

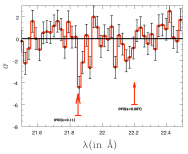


Fig. 6

Residuals, in σ, to the best fitting model (a powerlaw corrected by a multiplicative 'spline' model, and three negative gaussians at the positions of the z=0 OVII Kα and OVI Kα, and the $z=z_{sou}$ OVII Kα) of the 21-22.5 portion of the total RGS spectrum of Mkn 421 published by Rasmussen and collaborators. Narrow negative residuals are clearly present at the postion of the z=0.011 WHIM system and, less prominently, at the position of the z=0.027 WHIM system detected in the Chandra LETG spectrum of Mkn 421. If two negative gaussians are added to the model, the best fit positions and EWs of these lines are fully consistent with those measured in the Chandra LETG spectrum of Mkn 421 (Cf Table 4 with Table 1).

CONCLUSIONS

The XMM-Newton RGS spectrum of Mkn 421 confirms at least one of the two OVII WHIM systems first detected with Chandra

References

Nicastro, F. et al., 2005a, Nature, 433, 495,
Nicastro, F. et al., 2005b, ApJ, 629, 700
Rasmussen, A. et al., 2007, ApJ,